DEATH FEIGNING IN CONOTRACHELUS NENUPHAR HERBST.

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Peculiarities in behavior of insects have many times been used with distinct advantage in the control of injurious forms. The heliotropic reaction of moths—that is, their tendency to fly towards the light—has given rise to the trap lantern; and a knowledge of the nocturnal habits of the malarial and yellow fever mosquitoes has made it possible for the diseases caused by these insects to be avoided by housing oneself during their period of activity. One of the most striking cases of the direct economic application of an instinct in insects is that of death feigning or "playing possum" in the plum curculio, *Conotrachelus nenuphar*, Herbst.

It is true that the introduction of arsenical sprays marks an epoch in the control of the curculio, and quite deservedly has caused the old method of "jarring" to be largely superseded by the newer one of spraying. The practice of "jarring", however, is still in vogue in sections where the spray pump has not come into general use. Therefore, a study of the features of the instinct is of interest, not only from the biological point of view, but also due to the fact that at a not remote time it provided the most effective measure of control for the plum curculio.

In speaking of the preventive measures for lessening the injury of this pest, Johnson and Girault (8: 1906), of the Bureau of Entomology, U. S. Department of Agriculture, have the following to say: "Among these jarring is the method which is perhaps in most general use in protecting plums and peaches, and by many orchardists it is believed to give the best results. Early observations upon the plum curculio showed that this insect has a habit of falling to the ground and "playing possum" when disturbed. A knowledge of this habit has led to the capture of the beetles on sheets, held or spread beneath the trees, the trees being jarred by a sudden forceful blow struck with a padded pole or mallet in order to dislodge the beetles." A field test of the efficiency of the method made by these same men in a Georgia orchard showed "that the amount of the

curculio damage in this orchard for the season was placed at about four per cent of the crop. In an adjacent orchard of 130,000 peach trees not jarred, curculio injury was placed at forty per cent of the crop."

Owing to these facts, the writers considered it worth while to devote their leisure time during the past summer to a study of some of the general features of this exceedingly interesting mode of behavior. The work of Holmes (5, 6, 7) on the water scorpion, *Ranatra quadri-dentata*, and of the Severins (10) on *Belostoma flumineum* and *Nepa apiculata* make an exhaustive study of little significance. The work embodied in this paper was done at Clemson College, S. C., during the latter part of June and the month of July, and consequently upon forms which had emerged at the earliest only a few weeks before.

Death Feigning Attitudes.

It was found possible to produce the feint by three methods, and when one was not successful, the others were employed. The one most used is the same as that by which it is evoked in the natural environment of the insect—by dropping it from some distance in the air. When the insect is allowed to fall to the top surface of a table from a height of a few inches, the feint seems to be as effectively produced, usually, as when dropped through a space of several feet. By pressing the lateral surfaces of the abdomen and thorax, at short intervals, either by means of the fingers or forceps, the same effect may be secured. A third method is that of grasping the insect between the thumb and forefinger and blowing a sudden breath upon the ventral surface of the abdomen and thorax.

There are two distinct postures assumed by the insect in feigning death. In the first (fig. 1, A), the insect draws the thoracic appendages closely against the ventral surface of the body. The first pair of legs extend forward and are tightly pressed against each side of the proboscis. The second and third pairs are closely flexed, and held securely against the ventral surface of the thorax and abdomen. In the second position, the legs are folded closely together and held somewhat perpendicular to the line of the body (fig. 1, B). The tarsi of the first two pairs of legs are drawn tightly against the tibiæ; but in the last pair they are held approximately parallel to the ventral surface of the thorax. The first position is usually the

one more easily evoked; the second being given upon more vigorous stimulation. However, there seems to be considerable individual variation in this respect, some curculios assuming the second position more readily than the first. It was found possible to elicit the two types of response in the several individuals experimented on in this connection.

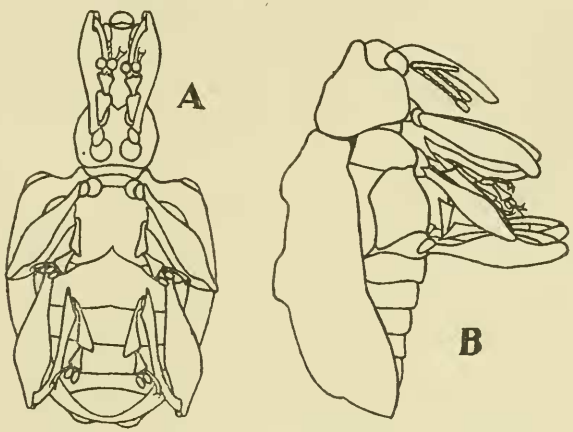

Figure 1. Attitudes assumed in the death feint.

Several specimens were starved to death, and others killed by a slow poisoning. All of these assumed a position very similar to that of the death feint indicated in fig. 1, B. The only difference to be noted was that in most cases, the tips of the tibiæ were farther apart, the legs being held not quite so perpendicular to the ventral surface of the thorax. This simulation of the natural death attitude in the death feint is in accord with the results of Kirby and Spence (9), who in the case of the dung-chafer, *Geotrupes sterocarius* found the same thing to occur. While not true in *Belostoma*, yet it is very closely parallel to what the Severins (10) found in *Nepa*, where "it becomes at times impossible to distinguish with the eye alone, a death feigning specimen from one that is really dead." However, in the majority of forms which have been studied, as recorded by Darwin (2) and other workers, the death attitude is found to be quite distinct in character from that assumed in the death feint.

Duration of Successive Death Feints.

It was the experience of Fabre (4) that when a large beetle, *Scarites gigas*, Fabre was put into five successive death feints, they lasted 17 minutes, then 20, 25, 33, and 50 minutes respectively. From this behavior, he draws the conclusion: Ils nous qu'en général le *Scarite* prolonge advantage sa pose inerte à mesure que l'epreuve se répète." The results of the Severins (10), however, do not agree with those of Fabre. They find a "wide variability in the duration of the first five feints in the different individuals under uniform conditions", and also "that the duration of successive death feints in each individual also varies."

Our experiments show results much more in accord with the Severins than with Fabre as observation of the following table will serve to show. Quite a wide range of variation is here to be seen, three of the six individuals showing a less duration of response in the fifth than in the first feint into which they were placed.

TABLE I.

Duration in Minutes of First Five Successive Death Feints in Six Curculios.

A	B	C	D	E	F	Averages
1.	10.	8.	6.	6.	3.	5.66
12.	2.	11.	2.	8.5	5.5	6.83
2.5	5.5	5.5	2.5	2.	9.	4.66
3.	1.5	2.5	1.	1.	10.	3.16
8.	3.	1.5	1.	7.	28.	8.

Six specimens were tested in order to determine the length of time the feint might be successively induced. Holmes (6) found in the case of ten *Ranatras* successively put into death feints, that these were continued without interruption from 9 a. m. to 5 p. m., when the last specimen refused to feign longer. The Severins (10) found it possible in the case of *Belostoma* to induce feints successively for a total of five hours. The responses of the curculio were very much less pronounced than was the case of these forms. Feints could not be elicited

successively for a period of greater length than two hours, fifty-three representing the largest number of feints successively produced in a single individual. The feints, after the first several, tended to show a decrease in duration, some of them continuing for only a few seconds. Finally the curculio refused to feign longer, no matter how treated, and in many cases made strenuous efforts to fly away.

The muscular system of the insect, while in the death feint, is in a tensely contracted condition. When held in a pair of forceps by the tip of one tibia, the entire body may be held out horizontally without signs of bending or movement on the part of the curculio. After a short time, however, the weight of the body causes a gradual relaxation of the leg muscles, and the animal is inclined downwards. Holmes (7) found the same thing to hold true in *Ranatra*, and says: "It is as if a man were seized below the knee and held out straight, face upward, without causing the knee to bend, only the legs of a *Ranatra* are several times more slender than those of the most attenuated of the human species, and the muscular tension which the insect maintains must therefore be intense." Undoubtedly, the acclimatisation of the insect to the extent that failure to respond with the death feint occurs after several successive periods of it have been passed through is to be explained in part at least as due to the muscular fatigue resulting from this rigidly contracted condition.

Effect of Temperatures on the Death Feint.

According to DeGeer (3), from his work on a small timber-boring beetle, *Anobrium pertinax*, "you may maim them, pull them limb from limb, roast them alive over a slow fire, but you will not gain your end; not a joint will they move, nor show by the least symptom that they suffer pain." In order to determine whether such a condition held in *Conotrachelus nenuphar*, many feigning specimens were placed on a thin piece of glass and gradually heated over the flame of an alcohol lamp. Though this experiment was repeated many times, the insects without a single exception, recovered activity as soon as the glass became heated. Individuals with the abdomen removed, others consisting of only the head and prothorax, and still others with all of the appendages removed, were placed in the

death feint and subjected to the same conditions as the normal ones, but not a one of them was found which would allow itself to be injured by the heat before attempting to escape.

Several specimens were taken and the time of six successive death feints was determined, and found to compare very closely with the results given in Table 1. These individuals were then placed, ventral surface uppermost, on a thin glass plate which was in contact with a block of ice. For approximately one minute the curculios made no movement. Then the abdomen was raised upwards out of the wing covers, as though to remove it from contact with the cold glass. The wing covers were then slowly spread away from under the body until they were well open. The legs were partially relaxed, but the movement was so gradual as to be almost imperceptible. This position was continued for a short time, and then the wing covers were drawn to their former position, the legs again becoming rigidly contracted. The insects were again motionless, and continued so until removal from the glass, forty minutes later. After a short interval had elapsed from the time of their removal, activity was manifested almost simultaneously among them. It was now found very difficult to induce these individuals to feign death.

A mixture of crushed ice and ammonium nitrate was now prepared and test tubes containing feigning curculios were placed in it. No movement whatever was manifested from the time they were placed in the test tube. When removed thirty minutes later, they were found to have sustained death as the result of the low temperatures (–15°C to –20°C) produced by this mixture.

These results in general agree with those of Fabre (4) on the Buprestid, *Capnoides tenebrinionis* Lin; and Holmes (6) on *Ranatra*, who find that cold has the effect of increasing the duration of the death feint to a marked degree.

Influence of Gases on Death Feint.

Many curculios were induced to feign death, and test tubes containing a wad of cotton saturated with ether were slowly placed over them. Without exception, the curculios revived almost instantly, many of them recovering before the tube touched the table. The same experiment was made with

chloroform, carbon di-sulphide, and carbon-di-oxide with similar results. Mutilated specimens put into the death feint were also tested and it was found that the most of them responded in the same manner. Thus in the case of the gases, as in that of heat, we see an adaptive feature in the nature of the instinct that tends to remove the animal from a stimulus of such a character as would result in injury to the organism.

Effect of Mutilations.

Holmes (6) found in *Ranatra*, that the appendages could be removed one by one, while the animal was in the death feint without evoking any response from the insect. The Severins (10) found in *Belostoma* that "if one of the limbs be snipped in two with a pair of fine scissors, the bug may not respond at all, or the limb may twitch or quiver, or the insect may right itself and scramble eagerly to get away. One or two repetitions of this experiment with those specimens which did not come out of the death feint immediately after the cut was made were sufficient to bring them out." In the case of *Nepa*, however, the results were more in accord with those reported on *Ranatra*.

The appendages of eight feigning curculios were removed one by one. With the exception of two of these curculios, every one of them showed absolutely no signs of recovery from the feint until several minutes after the operation. In the case of these two, recovering activity took place immediately after severing the first appendage. They were very easily made to feign again, and the operation proceeded without any apparent objection on their part.

Seven feigning individuals were decapitated with a pair of small, sharp scissors. The result was an immediate relaxation of the legs followed by efforts on the part of the body to right itself. In one case the wings were outstretched as though attempting to fly. The bodies were placed in the normal position with the result, however, that only two of them walked in a co-ordinated manner, and these for only a short time. This behavior is no doubt due to the shock effects of the operation. It was found possible to induce the death feint in these decapitated specimens, but with much more difficulty and with a shorter period in the duration of the response than was the case in the normal specimens.

Several specimens were placed in the death feint, and the abdomen of each was clipped away. No movement was made except a slight twitching of the tarsi in a few of the specimens. The insects remained in the feigning attitude for the normal length of time, and upon recovering activity walked about in a perfectly co-ordinated manner, except for the difficulty of balancing the body. They were thrown into the feint in this condition with about as much readiness as were the normal specimens.

The next operation performed was to sever the body between the prothorax and the mesothorax. The result without exception was an instant manifestation of activity on the part of the body, in some cases the wings becoming extended as if to fly. The head and prothorax, however, showed no shock effects of the operation, but remained in the feint for some time afterwards. This portion of the body could be readily induced to feign death, but the posterior part only to a very slight degree even upon vigorous stimulation. These results in general accord with those of investigators on other forms.

Nature of the Instinct.

The instinct of feigning death occurs in almost all of the orders of insects. While it is perhaps within this group that it reaches its most marked development, it is to be found to a slight extent in all of the higher phyla of the animal kingdom. It has been studied by Holmes in the amphipod crustaceans, and has been found by Andrews (1) in the breeding habits of the cray-fish. It occurs rarely among the fishes, and to a certain extent in the amphibians. In varying degrees, it is found expressed in the reptiles and birds; while among the mammals, from the behavior of the opossum, the common synonym "playing possum" has come to be derived.

It is Holmes' (5) conclusion from his work on the amphipod, *Talorchestia longicornis*, "that the death feigning instinct of *Talorchestia longicornis* is an instinct which has its roots in the thigmotactic response common among amphipods." The Severins (10) say: "Among aquatic *Hemiptera*, the death feint may have arisen out of positively thigmotactic propensities which are manifested to such a marked degree by various members of the families *Belostomatidæ and Nepidæ*." It is evident without statement, from the results discussed in this

paper, that the behavior of *Conotrachelus* serves to corroborate these conclusions and it is a striking fact that the response can be secured upon such slight contact stimulus, scarcely more than a touch being necessary to elicit a well marked death feint. The fact that the body deprived of its head, can be induced to give the response, removes the greater part of the psychic speculation in regard to the nature of the instinct.

Just what the value of it to the curculio in its native environment may be is largely a matter for conjecture; but that it has been used very effectively in combatting this common and injurious insect remains an incontrovertible fact.

It is with grateful appreciation that the writers here express their indebtedness to Dr. S. J. Holmes for the valuable suggestions arising from his critical reading of this article.

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